R for Travel Demand Modelers

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Overview

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This will be a quick overview:

"Curiosity Building" rather than "Capacity Building"

Overview

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1. What R is, and why it matters
2. A Quick Tour of R
3. Trying R yourself

What is R?

- Free Software Environment for Data Analysis and Programming

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  - Infoworld 2010 BOSS Award
    (Best Open Source Software)

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The goal of R is "to turn ideas into software, quickly and faithfully"

R "encourages you to slide into programming, perhaps without noticing"

Why is R called an 'Environment'?

"The term 'environment' is intended to characterize R as a fully planned and coherent system, rather than an incremental accretion of very specific and inflexible tools, as is frequently the case with other data analysis software.

"Many users think of R as a statistics system. We prefer to think of it as an environment within which statistical techniques are implemented."

From the R website (`http://www.r-project.org`)

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- Access to thousands of well-tested user-contributed packages, and tools to write your own
- Extensive documentation
- Support for Windows (32- and 64-bit), Macintosh, and Linux

Why Should I be Interested in R?

R is

- Interactive
- Fast
- Flexible
- Expressive
- Not Too Hard to Learn

Plus R is portable and scalable:

- You don't need administrator rights to run
- Commands run identically on all operating systems
- You can use it on your desktop
- You can write, save and distribute sophisticated sets of data and commands for others to use

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A *Really* Quick Tour of R

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A *Really* Quick Tour of R

Caution! We're going to move very fast

But the R code from this presentation is available...

... and the presentation itself was written in R (and LaTeX)

More on that later.

Getting Started with R

The usual way of interacting with R is through its GUI.
(Graphical User Interface)

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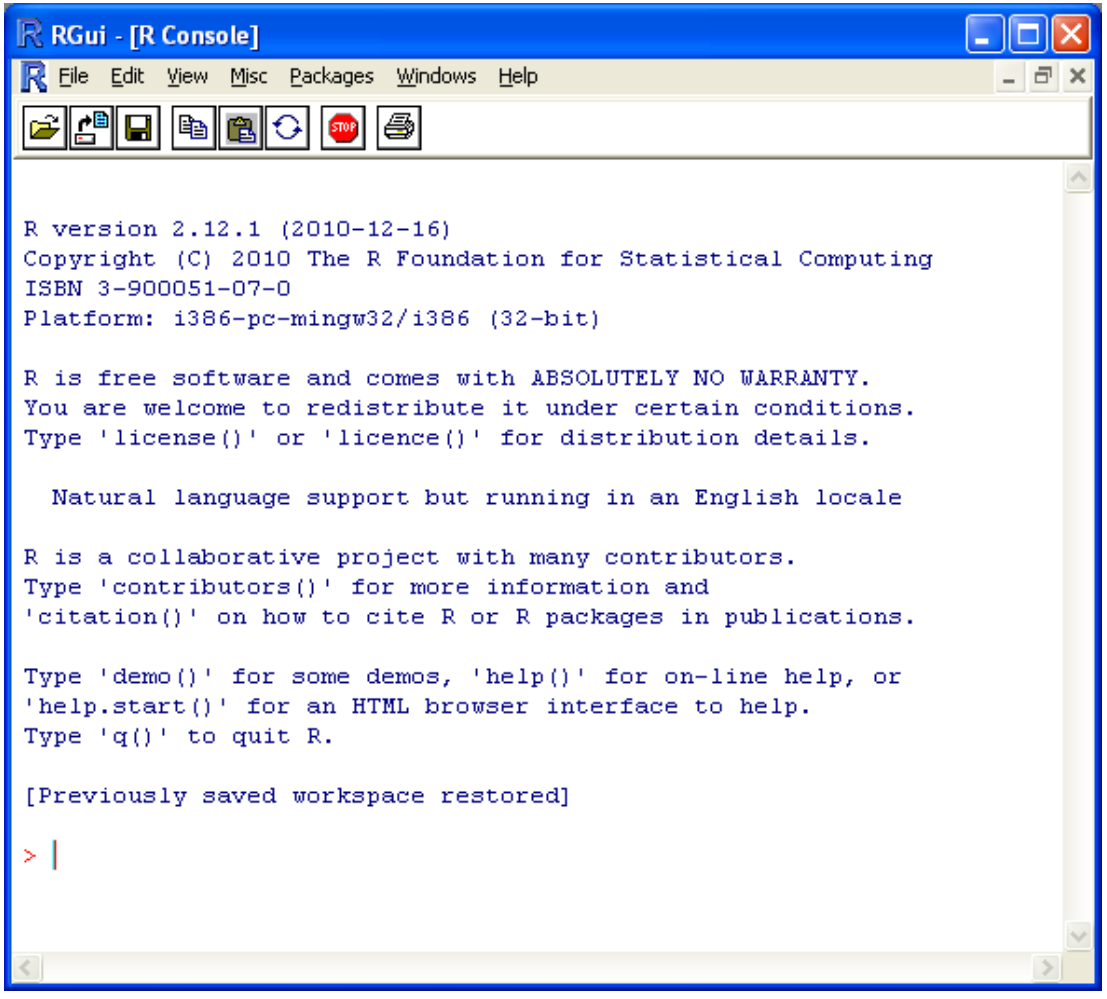
The program `Rgui` opens a window into which you type commands.

Getting Started with R

The RGui window looks like this:



Handy R Commands

The most important R commands are these:

- `help.start()` which launches the help system
- `q()` which exits the program

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2. `.Rhistory`: a list of all the commands you entered
   - Commands in `.Rhistory` may be copied to other script files for later use
   - Run scripts with `Rterm` or `Rscript`
   - Or use the `source()` function in `RGui`

Recap

To do useful things in R:

- Start RGui

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- Start `RGui`
- Enter `help.start()` to figure out what to do
- Enter other commands
- Use `q()` to quit

Approaching the R Language

For the rest of this tour of R we'll show some examples of R code and output.

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Reminder: The goal here is not to teach you R but to show you what it can do.

Welcome to R

R understands

- Integers

```
> 2
```

```
[1] 2
```

Welcome to R

R understands

- Integers

  ```
  > 2
  [1] 2
  ```

- Floating point numbers

  ```
  > 3.1415924
  [1] 3.141592
  ```

Welcome to R

R understands

- Integers

```
> 2
[1] 2
```

- Floating point numbers

```
> 3.1415924
[1] 3.141592
```

- Character strings

```
> "Hello, world"
[1] "Hello, world"
```

R Functions

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```
> length(2)  # One number is still a vector
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And here is a function that reports the length of a vector:

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> length(2)  # One number is still a vector
```

```
[1] 1
```

Here is a function to get help about a function:

```
> help("length")
```

R Vectors

Here is a function to create a vector:

```
> c(1,2,3,4)  # concatenate values
[1] 1 2 3 4
> 1:4
[1] 1 2 3 4
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Multiplication by a scalar

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[1] 2 4 6 8
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Multiplication by a scalar

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> c(1, 2, 3, 4) * 2
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```

Element by Element Division (R also does linear algebra)

```
> c(8, 27, 64)/c(2, 3, 4)
[1]  4  9 16
```

Statistics

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[1] 0.28290481 0.07866804 0.48956254 0.19959806
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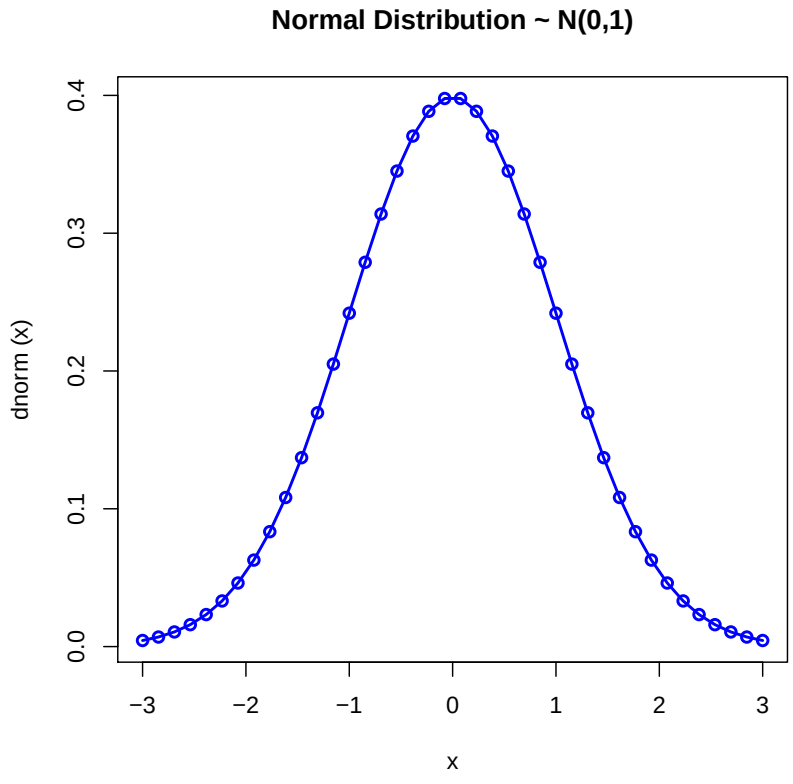
> dnorm(1.8,mean=2,sd=0.5) # normal density
[1] 0.7365403
> sample(5)     # 5 integers in random order
[1] 2 3 5 1 4
> sample(56,5)  # 5 random integers between 1 and 56
[1] 26 39 19 22  8
> sample(46,1)  # 1 random integer between 1 and 46
[1] 25
```

Plotting

Here is a graph of a normal distribution N(0,1)

```
> plot(dnorm,from=-3,to=3,n=40,
+       col="blue",type='o',lwd=2,
+       main='Normal Distribution ~ N(0,1)')
```



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The basic R way to make a variable::

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Find out what objects you have:

```
> objects()
[1] "seq4"    "seq4.a"  "seq4.eq"
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[1] "seq4"    "seq4.a"  "seq4.eq"
```

Using a Unix-like alternative:

```
> ls()
```

```
[1] "seq4"    "seq4.a"  "seq4.eq"
```

Indexing Vectors

Indexing a vector extracts some of its elements

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> v <- c('A','B','C','D')
> v[3]        # A single element
```

```
[1] "C"
```

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> v <- c('A','B','C','D')
> v[3]        # A single element
```

```
[1] "C"
```

```
> v[1:2]      # A pair of elements
```

```
[1] "A" "B"
```

Indexing Vectors

Indexing a vector extracts some of its elements

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> v <- c('A','B','C','D')
> v[3]       # A single element
[1] "C"
> v[1:2]     # A pair of elements
[1] "A" "B"
> idx <- c(1,4)
> v[idx] # Using a vector to index a vector
[1] "A" "D"
```

Indexing Vectors

Indexing a vector extracts some of its elements

```
> v <- c('A','B','C','D')
> v[3]       # A single element

[1] "C"

> v[1:2]     # A pair of elements

[1] "A" "B"

> idx <- c(1,4)
> v[idx] # Using a vector to index a vector

[1] "A" "D"

> v[5]       # Oops, out of bounds!

[1] NA
```

Indexing Vectors

But what about this?

```
> v <- c("A", "B", "C", "D")
> v[c(1, 2, 1, 3, 1, 2)]
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[1] "A" "B" "A" "C" "A" "B"
```

Indexing Vectors

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```

```
[1] "A" "B" "A" "C" "A" "B"
```

Categorical data is stored in a "factor"

```
> f <- factor(c("HBO", "HBO", "HBW", "NHB", "HBW"))
> f
```

```
[1] HBO HBO HBW NHB HBW
Levels: HBO HBW NHB
```

```
> as.integer(f)
```

```
[1] 1 1 2 3 2
```

Factors are stored as integers, but are printed as levels

Matrices

A matrix is a two-dimensional vector.

```
> m <- matrix(1:9, ncol = 3)
> m
```

```
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
```

Matrices

A matrix is a two-dimensional vector.

```
> m <- matrix(1:9, ncol = 3)
> m
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
> m <- matrix(1:9, ncol = 3, byrow = TRUE)
> m
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

Matrices

Some other matrix operations:

```
> t(m)
```

```
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
```

```
> diag(m)
```

```
[1] 1 5 9
```

```
> diag(m) <- 0
```

Matrices

Some other matrix operations:

```
> det(m)

[1] 180

> eigen(m)

$values
[1]  9.768639 -7.214613 -2.554027


$vectors
           [,1]       [,2]       [,3]
[1,] -0.3449886 -0.1757094 -0.7662572
[2,] -0.5897528 -0.5700571  0.5871849
[3,] -0.7301880  0.8025965  0.2608905
```

Matrix Indexing

Matrix indexing extends vector indexing.

```
> m[2:3,2:3] # Matrix subset
```

```
     [,1] [,2]
[1,]    0    6
[2,]    8    0
```

```
> m[,3]      # Vector (drops unit dimensions)
```

```
[1] 3 6 0
```

Matrix Indexing

Matrix indexing extends vector indexing.

```
> m[2,3]      # Scalar (drops both dimensions)
[1] 6
> m[2,3,drop=FALSE] # 1 x 1 matrix
     [,1]
[1,]    6
```

Lists

A `list` is a sequence of arbitrary objects (which can have names)

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```
> a.list <- list(
+     Sequence=seq4,
+     Text=LETTERS[1:10]
+     )
> a.list

$Sequence
[1] 1 2 3 4


$Text
 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"
```

Object Structure

Find out what is in a list:

```
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[1] "Sequence" "Text"
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Explore an R object's detailed structure:

```
> str(a.list)
```

```
List of 2
 $ Sequence: int [1:4] 1 2 3 4
 $ Text    : chr [1:10] "A" "B" "C" "D" ...
```

Lists

Lists are indexed in various ways

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```
> a.list[2]     # second element as list
```

```
$Text
 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"
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```
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$Text
 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"

> a.list[[2]]  # second element as vector

 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"
```

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> a.list[2]     # second element as list

$Text
 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"

> a.list[[2]]  # second element as vector

 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"

> a.list$Text  # List element by Name

 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"
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> a.list$Text  # List element by Name

 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"

> a.list[["Text"]]  # Also by name

 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J"
```

Data Frames

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A `data.frame` is a list of vectors, all the same length.

```
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> names(df)    # The list of columns (or fields)

[1] "N" "S" "C"
```

The corresponding elements of each vector make up the rows

```
> df

  N  S   C
1 2  4   8
2 3  9  27
3 4 16  64
4 5 25 125
```

Indexing Data Frames

`data.frames` are indexed like matrices and lists

```
> df[2:3,2:3] # Subset
```

```
   S  C
2  9 27
3 16 64
```

```
> df[2]       # just the second column
```

```
   S
1  4
2  9
3 16
4 25
```

```
> df[[2]]     # second column as a vector
```

```
[1]  4  9 16 25
```

Indexing Data Frames

`data.frames` are indexed like matrices and lists

```
> df[2,]      # just the second row
```

```
  N S  C
2 3 9 27
```

Not a vector, since data.frames can have different types in each column

```
> df$S        # vector from 'S' column
```

```
[1]  4  9 16 25
```

```
> df[sample(nrow(df),1), ]  # random row
```

```
  N  S   C
4 5 25 125
```

Loading Data

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- R supports text formats directly.
  - Text data is imported with functions like `read.csv()`
- Packages support data in other formats (e.g. DBF, SAS Export, SPSS, Excel)

Loading Data: An Example

2009 National Household Transportation Survey (NHTS) data:

```
> download.file(
+     "http://nhts.ornl.gov/2009/download/Ascii.zip",
+     "NHTS-2009-ASCII.zip"
+     )
> unzip("NHTS-2009-ASCII.zip",exdir="NHTS-2009")
> dir("NHTS-2009")  # show files in the directory

> hh  <- read.csv("NHTS-2009/hhv2pub.csv")
> veh <- read.csv("NHTS-2009/vehv2pub.csv")
> day <- read.csv("NHTS-2009/dayv2pub.csv")
> per <- read.csv("NHTS-2009/perv2pub.csv")
> save(per,hh,veh,day,file="NHTS.Rdata")

> load("NHTS.Rdata")   # reload later
```

But What Can R *Really* Do?

Let's look at some results and just zoom past the code.

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- R supports "Reproducible Research" and "Literate Programming" (q.v.)
- This presentation itself was generated using R and other open source tools.
  - Get the presentation files from the file download area.
- You can study the code (and find all the mistakes)!

Trip Rates from NHTS

- Trips Per Person Per Day, by Purpose and Household Size

```
> print(trips.per.person.per.day)
```

	PURPOSE				
HHSIZE	HBO	HBSHOP	HBSOCREC	HBW	NHB
1	0.5053646	0.9330562	0.4571780	0.4104453	1.211096
2	1.1779582	1.7553935	0.9405527	0.9331598	2.408037
3	2.5857568	2.6211519	1.6863807	1.5631168	3.737891
4+	5.0528199	3.3497913	2.7294158	1.8686832	5.304584

DISCLAIMER:
This page shows how to use R, not how to analyze the NHTS.

Trip Rates from NHTS

- Trips Per Day, by Purpose

```
> print(mean.trips.per.day.by.purpose)

     HBO   HBSHOP HBSOCREC      HBW      NHB
2.089154 2.023070 1.328052 1.098461 2.938784
```

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Trip Rates from NHTS

- Trips Per Day, All Households

```
> print(mean.trips.per.day)
[1] 9.477522
```

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Trip Rates from NHTS

Here's how we did it:

```
> day.wt <- day[c("HOUSEID","WTTRDFIN",
+                 "TRIPPURP","TRVLCMIN")]
> hh.wt <- hh[c("HOUSEID","WTHHFIN","HHSIZE")]
> hh.wt$HHBIN <- with(hh.wt,{
+     cut(HHSIZE,
+         breaks=c(0,1,2,3,
+         max(HHSIZE)),
+         labels=c("1","2","3","4+"),
+         ordered_result=TRUE)
+     })
```

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Trip Rates from NHTS

Here's how we did it:

```
> trips <- merge(day.wt,hh.wt,by="HOUSEID")
> trips$PURPOSE <- factor(trips$TRIPPURP,
+                                    exclude=c("-9"))
```

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Trip Rates from NHTS

Here's how we did it:

```
> trips.person <- with(trips,{
+     aggregate(
+         trips["WTTRDFIN"],
+         by=list(PURPOSE=PURPOSE,HHBIN=HHBIN),
+         sum
+         )
+     })
> trips.person <- reshape(
+     trips.person,direction="wide",
+     idvar="HHBIN",timevar="PURPOSE",
+     v.names="WTTRDFIN"
+     )
> row.names(trips.person) <-
+         levels(trips.person$HHBIN)
```

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Trip Rates from NHTS

Here's how we did it:

```
> trips.person.day <-
+  data.matrix(trips.person[,2:length(trips.person)]/365)
> dimnames(trips.person.day) <-
+    list(
+       HHSIZE=levels(trips.person$HHBIN),
+       PURPOSE=levels(trips$PURPOSE)
+       )
> trips.hh <- with(hh.wt,{
+     aggregate(
+         hh.wt["WTHHFIN"],
+         by=list(HHBIN=HHBIN),
+         sum
+         )
+     })
```

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Trip Rates from NHTS

Here's how we did it:

```
> trips.per.person.per.day <-
+    sweep(trips.person.day,1,trips.hh$WTHHFIN,FUN="/")
> sum.trips.day <- colSums(trips.person.day)
> sum.hh <- sum(trips.hh$WTHHFIN)
> mean.trips.per.day.by.purpose <- sum.trips.day/sum.hh
> mean.trips.per.day <- sum(mean.trips.per.day.by.purpose)
```

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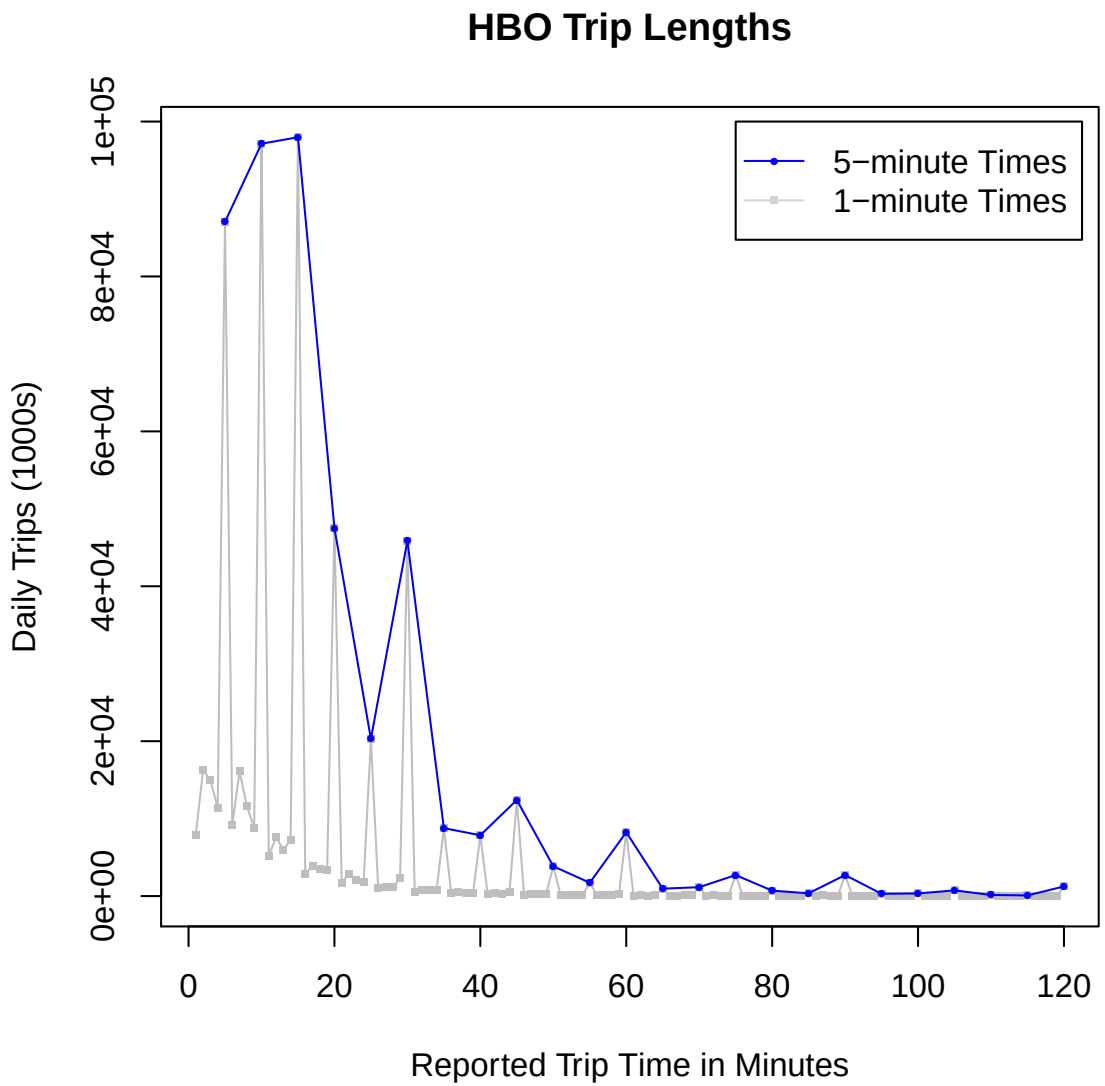
Trip Length Frequency Distributions

Trip Length Frequency Distributions from NHTS 2009



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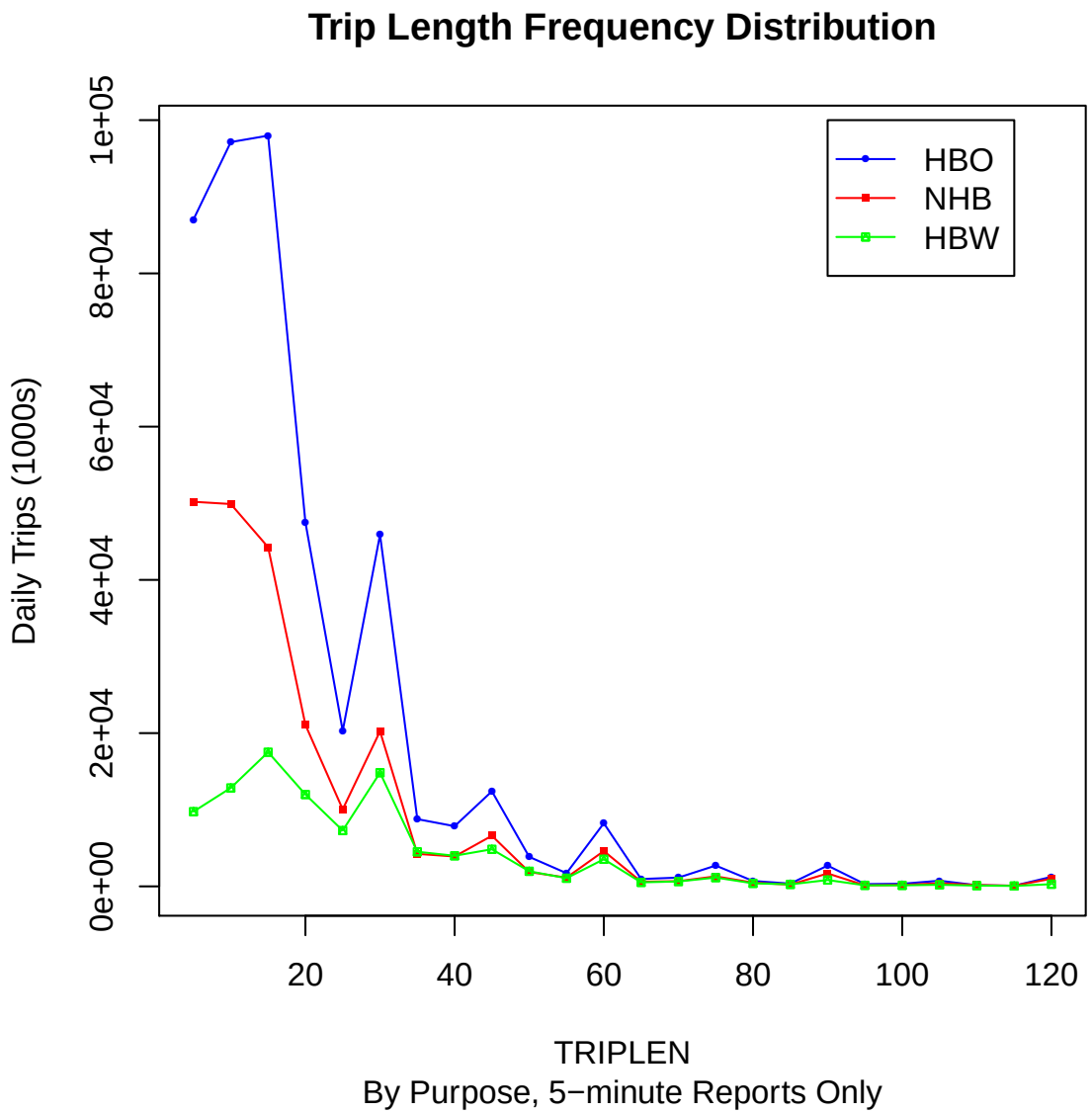

Trip Length Frequency Distributions

Here's how we did it:

```
> trips$SIMPPURP <- trips$PURPOSE
> recode <- which(
+   ! (   trips$PURPOSE %in% c("HBW","NHB"))
+           & !is.na(trips$PURPOSE )
+      )
> trips$SIMPPURP[recode] <- "HBO"
> trips$SIMPPURP <- factor(trips$SIMPPURP)
```

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Trip Length Frequency Distributions

Here's how we did it:

```
> trips$TRIPLEN.1 <- as.integer(
+     cut( trips$TRVLCMIN,
+          breaks=seq(0,120,1),
+          ORDERED_RESULT=TRUE )
+     )
> trip.dist.1 <- with( trips, {
+     aggregate(
+         data.frame(Trips=WTTRDFIN/365000),
+         by=list(Purpose=SIMPPURP,TRIPLEN=TRIPLEN.1),
+         sum)
+     })
```

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Trip Length Frequency Distributions

Here's how we did it:

```
> min.5 <- which(trips$TRVLCMIN%%5<0.1)
> trips[min.5,"TRIPLEN.5"] <- as.integer(
+     cut(
+         trips[min.5,"TRVLCMIN"],
+         breaks=seq(0,120,5),
+         ordered_result=TRUE,
+         )
+     ) * 5
> trip.dist.5 <- with( trips[min.5,], {
+     aggregate(
+         data.frame(Trips=WTTRDFIN/365000),
+         by=list(Purpose=SIMPPURP,TRIPLEN=TRIPLEN.5),
+         sum)
+     })
```

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Trip Length Frequency Distributions

Here's how we did it:

```
> nhb.5 = which(trip.dist.5$Purpose=="NHB")
> hbw.5 = which(trip.dist.5$Purpose=="HBW")
> hbo.5 = which(trip.dist.5$Purpose=="HBO")
> hbo.1 = which(trip.dist.1$Purpose=="HBO")
```

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Trip Length Frequency Distributions

Here's how we did it:

```
> plot(trip.dist.1[hbo.1,2:3],type='o',
+      col="gray",pch=15,cex=0.5,
+      main="HBO Trip Lengths",
+      xlab="Reported Trip Time in Minutes",
+   ylab="Daily Trips (1000s)")
> points(trip.dist.5[hbo.5,2:3],type='o',
+        col="blue",pch=16,cex=0.5)
> legend(75,100000,
+        c("5-minute Times","1-minute Times"),
+        col=c("blue","lightgray"),pch=c(16,15),
+        pt.cex=0.5,lty=1)
```

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Trip Length Frequency Distributions

Here's how we did it:

```
> plot(trip.dist.5[hbo.5,2:3],type='o',
+      col="blue",pch=16,cex=0.5,
+      main="Trip Length Frequency Distribution",
+      sub="By Purpose, 5-minute Reports Only",
+      ylab="Daily Trips (1000s)")
> points(trip.dist.5[nhb.5,2:3],type='o',
+        col="red",pch=15,cex=0.5)
> points(trip.dist.5[hbw.5,2:3],type='o',
+        col="green",pch=14,cex=0.5)
> legend(90,100000,c("HBO","NHB","HBW"),
+        col=c("blue","red","green"),
+        pch=c(16,15,14),pt.cex=0.5,lty=1)
```

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R Packages

- All we have used so far is "Base R"

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- R is extended with "packages"
- A package is a set of functions and data, with documentation

Using Packages

- `library()` function to load functions from a package

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Most packages exist in compiled versions for all platforms

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Navigating Packages

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- You'll find packages you want from tutorials and other reading
- "Task Views" tour packages for various subject areas
  - `http://cran.r-project.org/web/views`
- In addition to CRAN, there are several other important R Repositories:

  `http://www.bioconductor.org` Genomic research

  `http://r-forge.r-project.org` Development

  Look here for `travelr`, with functions for travel modeling

  `http://www.rforge.net` More Development

Interesting Packages

Spatial	`sp`, `maptools`, `rgdal`, `raster`, `spatstat`
Statistical	`MASS`, `nlme`, `nls`, `mlogit`, `survival`
Time Series	`forecast`, `tseries`
Bayesian Stats	`arm`, `bayesM`, `mcmc`, `sna`
GPS Analysis	`adehabitat`
Travel Modeling	`travelr` (from R-Forge)

Installing Packages

- Once you know what you want, installing packages is simple

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- From the GUI menu, choose "Install Packages..."
- Or `install.packages()` like this:

```
> install.packages(c("rgdal", "sp"))
```

```
> # Non-standard repository:
> install.packages("travelr",
+         repos="http://r-forge.r-project.org")
```

Learning About R Packages

- In addition to help, many functions have working examples

```
> library(rgdal)
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- The vignette serves two purposes:
  1. Shows how to use the package in common applications
  2. Delivers working code (used in the package build/test process)
- Browse vignettes for installed packages:

```
> browseVignettes()
```

R Spatial Data

Here is an example of a map generated from R using one of the spatial analysis libraries

```
> library(sp)   # spatial data library
> load("alx.network.Rdata")   # sample data
```

(See the presentation source for the rest...)

R Spatial Data

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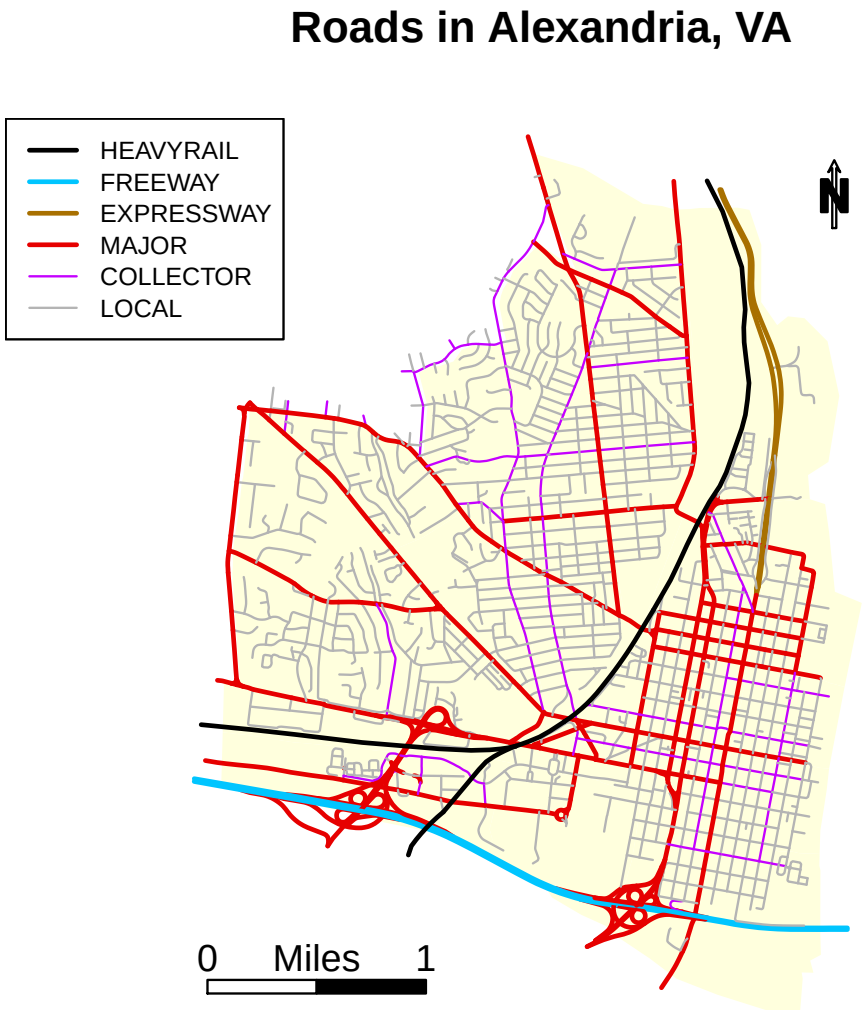

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  - "CRAN", pronounced "See-Ran" or "Kran"
- `http://cran.r-project.org/mirrors.html`
  - Pick a mirror site near you.

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  - `http://www.r-project.org`
- The Tutorial Introduction can be read without installing R
  - `http://cran.r-project.org/doc/manuals/R-intro.html`

Accessing this Presentation

The file pod for this web presentation includes a zip archive with the following files:

Travel-Modeling-With-R.pdf Finished presentation
Travel-Modeling-WIth-R.R Just the R commands
Travel-Modeling-With-R.Rnw R + LaTeX source code
ReadMe.txt A text file explaining how to build the presentation
Rgui.png Screenshot of R GUI window
Rlogo.png R Logo
Sweave.sty Support file for building the Presentation
alx.network.Rdata Sample spatial data (R format)

If you want to build the presentation from the `.Rnw` file, you will need a working LaTeX installation. The MikTeX package (`http://miktex.org`) works well on Windows.

Otherwise, to try the code, you only need R itself, plus a working internet connection.